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ANGELA M. WICKS, JOHN K. VISICH, and SUHONG LI

Abstract. Radio frequency identification (RFID) technology has recently begun to receive increased interest from practitioners and academicians. This interest is driven by mandates from major retailers such as Wal-Mart, Target and Metro Group, and the United States Department of Defense, in order to increase the efficiency and visibility of material and information flows in the supply chain. However, supply chain managers do not have a monopoly on the deployment of RFID. In this article, the authors discuss the potential benefits, the areas of applications, the implementation challenges, and the corresponding strategies of RFID in hospital environments.

Key words: adoption, healthcare, implementation, RFID, supply chain management

In hospital settings, patient safety is critically important; lives are at stake, and zero defects should be the established standard. At the same time, hospitals are pressured to reduce costs. Therefore, when developing strategic objectives, technologies that reduce operating expenses while providing increased patient safety must be thoroughly tested and evaluated. Radio frequency identification (RFID) is one technology that holds great promise. "RFID . . . [has] the potential to revolutionize business processes across a wide range of industries including . . . health care" (The Journal of Commerce 2004, 1). RFID technology can be used to manage hospital patients' medications, medical supply usage, medical processes, and outpatient compliance with medication treatment plans after hospital discharge.

Government forces, along with retailers, are major drivers of RFID technology and the rapid growth of the RFID market. The Department of Defense has issued warnings that drugs could become the target of terrorist attacks; the warnings are based on Interpol warnings about terrorist involvement in counterfeiting (Kontnik and Dahod 2004). Therefore, the U.S. Food and Drug Administration (FDA) of the Department of Health and Human Services (HHS) has issued a recommendation that the pharmaceutical industry implement RFID tagging on all drugs at the unit level by 2007 to track drugs throughout the economy and prevent drug counterfeiting and distribution by terrorist groups and other criminal elements (Becker 2004; Brewin 2004; U.S. Department of Health and Human Services, Food and Drug Administration 2004). In response, the overall global market for RFID is expected to grow at the annual rate of 45% from $965 million in 2002 to $4.6 billion by 2007 (Hickey 2004; Ward 2004). Sales of RFID technology for supply chain applications are expected to grow at the rate of 38% (from sale of $89 million in 2002 to $448.4 million by

Angela M. Wicks, PhD, is an assistant professor in the Management Department at Bryant University, Smithfield, RI. She received her PhD in Operations Management from the University of Houston in 2004. **John K. Visich**, PhD, is an assistant professor in the Management Department at Bryant University, Smithfield, RI. He received his PhD in Operations Management from the University of Houston, where he received the Melcher Award for Excellence in Teaching by a Doctoral Candidate. **Suhong Li**, PhD, is assistant professor of Computer Information Systems at Bryant University, Smithfield, RI. She earned her PhD from the University of Toledo in 2002.
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2007) (Hickey), with healthcare included in the top three fastest growing market segments (Hickey). Nearly one-fifth of healthcare respondents to an *Information Week 500* survey say they have tested and deployed RFID technology (McGee 2004).

With the widespread implementation of RFID technology, hospitals must develop an RFID infrastructure immediately. Otherwise, they could be facing an environment in which "other industries will impose their standards" (Becker 2004). Therefore, in this study we focus on RFID technology in hospital environments, discussing applications and benefits, implementation challenges, and implementation strategies. Our research will offer useful guidance for hospitals that wish to implement RFID and offer a springboard for future research in this area.

Hospital Literature Review

Little academic research in hospital-specific applications of RFID exists. Hosaka (2004) simulated hospital bedside and nursing station conditions to determine the range of the tag and antenna. The study presented several ideas to solve implementation issues for hospital use. Glabman (2004) presented a theoretical article that examined the various applications for RFID in healthcare. In this article, we will extend Glabman's study to include implementation issues of RFID in the hospital industry.

Although widespread adoption and implementation of RFID technology has not yet occurred in hospitals, some leaders have emerged. Agility Healthcare Solutions is providing Bon Secours Health System, Richmond, Virginia, with RFID tags for medical devices; the hospital is "tagging approximately 12,000 pieces of movable equipment at its three hospitals, including IV (intravenous) poles, pumps, wheelchairs, stretchers and hospital beds" (Becker 2004, 38). Secours' employees were spending 25–33% of their time searching for equipment and losing about 10% of their inventory annually; RFID tags saved nurses time in locating equipment (Glabman 2004). Ascension Health, headquartered in St. Louis, Missouri, is investing in Radianse, a manufacturer of RFID tracking systems (Becker). St. Luke's Health System, Kansas City, Missouri, is considering implementing bedside RFID technology in its new hospital opening in 2006 (Becker). St. Luke's is currently using bar codes for all inpatient and outpatient laboratory tests but is considering moving directly to RFID tags. St. Luke's found that bar coding reduced medical errors; some problems still exist, however. For example, hand washing degrades bar codes, and the technology does not track ambulatory patients. Beth Israel Medical Center, New York City, began testing an equipment tracking system to identify under- and overutilization problems so that the company can accurately determine when to purchase or reallocate equipment (McGee 2004). Cardinal Health Inc., the leading supplier of products and services supporting the healthcare industry, is placing RFID tags on surgical medical products to ensure no items are "left inside the patient during surgery" (McGee, 105).

Potential Benefits of RFID Technology in the Healthcare Industry

Benefits to the hospital not only include improved supply chain efficiency, but can also translate into saving lives or improving patient outcomes. The technology can increase patient safety, speed critical treatments, and provide better tracking of patient drug-treatment compliance that leads to better follow-up treatment. Benefits of RFID also include lower direct and indirect labor costs.

Rising healthcare costs are a major concern, and hospitals are actively seeking ways to reduce expenses. Agility Healthcare Solutions CEO Fran Dirksmeier, "estimates a 200-bed hospital can save $600,000 annually from less shrinkage, fewer rentals, deferral of new purchases and improved staff productivity. A 500 bed hospital could save $1 million annually" (Glabman 2004). Advocate Good Shepherd Hospital, Barrington, Illinois, implemented RFID in 2003 to help manage inventory; annual inventory losses were cut by about 10% (Glabman). Many hospitals incur high costs related to lost, misplaced, or stolen equipment. For example, $4 million worth of equipment was unaccounted for at Jackson Memorial Hospital, Miami, Florida, in 2003; the hospital plans to implement RFID equipment-tracking technology within two years (Glabman). Holy Name Hospital, a 361-bed facility in Teaneck, New Jersey, found that RFID-tagged equipment saved time in locating equipment and reduced rental costs because equipment was more fully used (Glabman). Medical equipment can also be tagged to monitor usage, improve billing accuracy, and schedule maintenance.

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As hospitals seek to reduce costs, it is important that patient satisfaction is not adversely affected. RFID can improve patient treatment and safety by reducing medical errors, improving the security of medicine and the facility, and improving patient compliance. The Institute of Medicine estimates that "tens of thousands of deaths and injuries [are] caused by medical mistakes every year" (McGee 2004, 101). The FDA estimates that number to be nearly 500,000 (McGee). However, the FDA also estimates that half of the drug errors are preventable; the introduction of integrated information technology could greatly reduce that number. "In a paper-based environment, medical errors frequently approach 40%. Of those, 39% are made at the prescription point, 12% are caused by transcription errors, 11% in dispensing . . . Equipping pharmacists, doctors, and bedside nurses with wireless devices that incorporate bar codes or RFID will nearly eliminate all those errors" (Klein 2003, 100). For example, nurses could electronically scan the patient's RFID tag and the drug's RFID tag to ensure that the correct drug and correct dosage are administered to the patient. The tags could provide alerts about possible patient allergies and potential drug interaction problems (McGee). Attaching tags to the patient and the patient's medical articles could monitor the patient's environment and movement within the facility (Hosaka 2004). RFID technology could also be used to scan prescriptions and transmit them to the pharmacy to eliminate hand-written prescriptions and reduce prescription fill-rate errors (Murphy 2003). In addition, the tags could be used to identify out-of-date products to reduce the possibility of a fatal or ineffective dose.

RFID technology can also be used to improve the security of a hospital or treatment center by controlling facility access. Employee and patient tags could indicate when a restricted area is entered. When such an event occurs, an alarm would be triggered to alert security personnel.

Mediary Corporation has invented the Med-ic Electronic Compliance Monitor, a technology that embeds RFID tags into blister packs of prescription packages. The "new blister packaging system . . . can monitor electronically the date and the time a patient opens a package of medicine and takes out a pill" (Parks 2003, 26). In outpatient settings, the patient would return the used packaging to the clinic, the package would be scanned, and patient usage patterns plotted. The system would provide more effective evaluation of patient compliance with prescription medication therapy because skipped or doubled doses would be apparent (Parks). The technology can also be extended to "alert the patient when it is time to take a pill" (Parks, 26). The RFID tag "can be tailored to specific clinical requirements, such as monitoring the temperature, vibration, humidity, radiation, light or shock to which the package might be exposed" (Parks, 28).

Managing blood distribution is "the stuff of supply chain nightmares, the kind that keep logistic professionals awake at 3 a.m. . . ." (Roberts 2004, 15), because they are dealing with a highly perishable, highly sensitive product that is always in short supply and is always difficult to procure (Roberts). Temperature-sensitive tags can provide accurate tracking—in real time—to ensure that blood stored at less than optimal temperatures would not be distributed to a patient. Other benefits include the ability to track tainted blood. All these factors will aid in protecting a hospital's blood supply.

Other RFID uses are available, including identifying, tracking, and locating patients, clinicians, equipment, supplies, and controlled drugs in hospital facilities (Miller 1999). Tags could be used to determine whether supplies and instruments had been sterilized (Miller). Miller suggests using RFID tags to track residents in long-term care facilities, monitor access to restricted areas, identify implantable medical devices, and scan information from implanted equipment.

The Navy is experimenting with using passive tags as tracking devices for patients in the battlefield. Wounded soldiers are tagged, and a healthcare worker then scans and uploads the information into a handheld scanner, entering the patient's condition and care (Schwartz 2004, 65). The system was field tested in Iraq in a 116-bed hospital in an operational environment. Implementation results included: (*a*) increased casualty accountability and documentation; (*b*) increased situational awareness; and (*c*) maximized use of resources (Collins, P. 2004). The Navy's system could be adapted to an emergency response system in which the patient is tagged in the field by the emergency team, and the patient's condition and treatment data are then scanned onto the tag and uploaded at the hospital. The intention would be to speed treatment and improve accuracy. Such a system can also provide more planning information to the

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hospital, such as requirements for emergency room staffing and usage requirements for X-rays and other ancillary services.

RFID would also eliminate "tens of thousands of deaths and injuries caused by medical mistakes every year" (McGee 2004, 101), and, according to U.S. Department of Health and Human Services Secretary, Tommy Thompson, "a good health-information system could save our economy $140 billion a year. That's about 10% of our total health-care spending, and that's a conservative estimate" (Whiting 2004). RFID will be a key component of the health information system.

Implementation Challenges

Currently, the costs associated with implementing and managing the tagging systems are the major problems associated with RFID. These costs include obtaining tags, applying tags to equipment or patients, purchasing tag readers, developing software programs and database systems, and integrating and maintaining the systems. Tags would have to be attached to everything. For a 1000-bed hospital, that could mean tagging 20,000 items per day (Hosaka 2004). The tags would have to be quite small and cost effective before such a system could be implemented, and decisions would have to be made regarding who would apply the tags. Hosaka suggests that the tags originate at hospital registration where the patient's information and tag numbers would be stored in a database; the tags would be distributed to the nursing station where they could be attached directly to larger items and attached to packaging for small items, such as syringes (Hosaka). The number of tags would be determined by the patient's estimated length of stay and unused tags could be reprogrammed. If tags were coated with medical silicon, they could be sterilized and reused until the tags degraded (Hosaka). According to a recent Healthcare Distribution Management Association's Healthcare Foundation study, integration costs are estimated to range from $10 to $16 million for large manufacturers and from $3 to $16 million for large distributors (Hosaka); these costs do not include the costs of hardware, data-processing software, or operating expenses. The tags are also relatively expensive; passive RFID tags cost approximately 10 cents per tag, whereas bar codes cost approximately 3 cents per sticker (Becker 2004, 38). The difference in total costs can be substantial. For example, a typical 800-bed hospital administers approximately 15,000 doses of medication a day (Becker), which equates to $1,050 per day difference in medication tagging costs alone.

The cleansing and analysis of RFID-generated data is also a major issue. The Elvis Presley Memorial Trauma Unit of Shelby County Regional Medical Center, Memphis, Tennessee, implemented an RFID patient-tracking system. The unit found that a significant amount of noise and "dirty data" are generated from an RFID-based system (Janz, Pitts, and Otondo 2004).

Unique implementation problems centering on patient confidentiality exist in hospital industries. How can products be named so that each product has a unique identifier yet still maintains patient confidentiality? If the tags are unique, anyone knowing tag data will know the patient's drug therapy program, disease, illness, or type of injury. These issues relate to data sharing and consumer–patient privacy concerns and present greater costs and challenges in the hospital industry than they do in other industries adopting RFID technology (Collins J. 2004). Privacy advocates are concerned that third parties might be able to determine what medicines a person was taking by scanning pill bottles carried by the patient. To prevent snooping, the tags would need either a random number stored in a secure database to identify the medicine or a security code to access the data stored on the chip. Either security option would increase the cost of chips and readers (Kontnik and Dahod 2004). Healthcare providers need to comply with the U.S. Department of Health and Human Services Health Insurance Portability and Accountability Act (HIPAA), which requires an organization to take "reasonable" measures to safeguard electronic health data (Fenner 2004).

Overcoming Implementation Problems

Although cost is a major impediment to RFID implementation, increased demand for RFID tags and supporting systems will drive technology to improve the system and lower associated costs. Alien Technology Corporation, Morgan Hill, California, has patented a manufacturing and packaging process that is purported to greatly reduce the price of RFID tags; Alien's goal is to reduce the cost to 5 cents or less per tag. Smartcode Corporation, New York City, has also patented a new technology that could produce tags at a cost of five to 10 cents per tag; that price is for volume orders of at least a billion tags, however. Companies can also

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outsource. Secours has contracted with Agility Healthcare Solutions to provide medical equipment and monitor the systems for a monthly fee. Secours estimated a cost of $750,000 to perform these services in house; the company is expecting an annual savings of $200,000 from outsourcing and a conservative savings of $203,000 from its ability to track equipment, thus preventing theft and loss (Glabman 2004). Hospitals can also take advantage of the research from the newly created FedEx Institute of Technology, located at the University of Memphis, Tennessee; the institute's mission is to bring an interdisciplinary approach to supply chain research so that "RFID tags can track goods or the progress of patients through a health care facility" (Cottrill 2003, 1).

The potential healthcare applications and benefits to the healthcare industry—together with the many unique implementation problems in the healthcare industry faces—have prompted the formation of an Healthcare EDI Coalition (HEDIC) working within the Health Industry Business Communication Council. "The workgroup's key objectives are to identify the issues involved with the use of RFID in healthcare applications, to work proactively with technology providers and other standards organizations in developing a response to those issues and to develop guidance and specification for implementing RFID technologies in healthcare applications" (Miller 1999). Major topics at the 1999 National Conference and Technology Exposition sponsored by HEDIC included seminars on transition, integration, and implementation of RFID technology. According to the conference program, "the future is here for most stakeholders" (Miller, 59). The FDA and the Joint Commission on Accreditation of Hospitals are encouraging bedside bar coding by the beginning of January 2007, but, according to Becker (2004), perhaps RFID could do a better job of tagging patients, workers, and medications, and organizations could benefit from moving directly to RFID.

Other ideas include adopting the Electronic Product Code standard, where the industry could establish common business practices to handle exceptions and set consistent best practices; this could be addressed by applying Malcolm Baldrige healthcare criteria standards. Companies could also set up security infrastructures and partnerships along the supply chain to facilitate implementation and to lower costs, such as the Blue Cross/Tufts partnership.

Conclusion

The same benefits and problems of RFID implementation that exist in hospitals also exist in other industry sectors. In this article, we attempted to focus on the issues more specific to the hospitals; it should be noted, however, that the real benefit of RFID technology comes from going above and beyond compliance and investigating other applications of RFID to improve healthcare marketing efforts, operational effectiveness and efficiency, and patient satisfaction. Mandates from the government and major retailers will drive the adoption of RFID technology in healthcare, and hospitals will have no choice but to implement RFID systems. Even if the true benefits will not be realized for several years, establishing the base RFID infrastructure today is the key driver for total supply chain adoption and benefit realization tomorrow.

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